Weather for Commercial Transport Utilizing a Hybrid Data Link

WxAP Briefing

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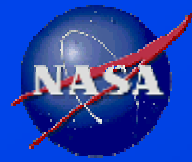
Commercial Transport Goal



The specific goal of the Commercial Transport task area is to develop a weather dissemination capability for commercial transport aircraft within a national network that includes:

- Transmission of on-board sensed turbulence information to ground users and between aircraft.
- Broadcast graphical weather products to the pilot.

Architecture Design

- Due to the near-term focus of the WINCOMM project it was necessary to select datalinks that already reside on commercial transport aircraft or were on a path for installation in the near future.

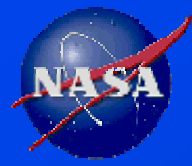
- No single datalink can currently satisfy the project requirements for air-to-air, ground-to-air broadcast, and air-to-ground two-way communication to this class of aircraft. It was therefore necessary to design a hybrid communication architecture to meet the project objectives

Objectives

Demonstrate a path to implementation for the following value added objectives:

- Dissemination of data from own ship turbulence events to other aircraft and ground users.
- Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.
- Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.

Objectives 1&2



- Dissemination of data from own ship turbulence events to other aircraft and ground users.

- Receive, process and deliver valid turbulence warnings to the cockpit from other equipped aircraft.

Need an Air-to-Air link

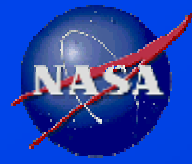
Air-to-Air

A natural match for air-to-air communication is one of the Automatic Dependent Surveillance Broadcast (ADS-B) links.

- On July 1, 2002, the FAA announced the ADS-B link decision [5], selecting the 1090 Extended Squitter link for air carrier and private/commercial operators of high performance aircraft

1090ES datalink was selected by WINCOMM to fulfill the air-to-air datalink requirements for the transmission of turbulence alerts.

Turbulence Alert Message



- The turbulence alert message will consist of the following parameters:

1. Time
2. Latitude
3. Longitude
4. Altitude
5. Processed Normal Load
6. Processed Aircraft Constant

- Standard ADS-B messages already contain the first four parameters, it is only necessary to broadcast two additional parameters. These two additional parameters are each eight bits long, totaling an additional 16 bits to be transmitted. The additional parameters will be formatted as a payload to a standard ADS-B message, in compliance with DO–260

.

Turbulence Alert Message

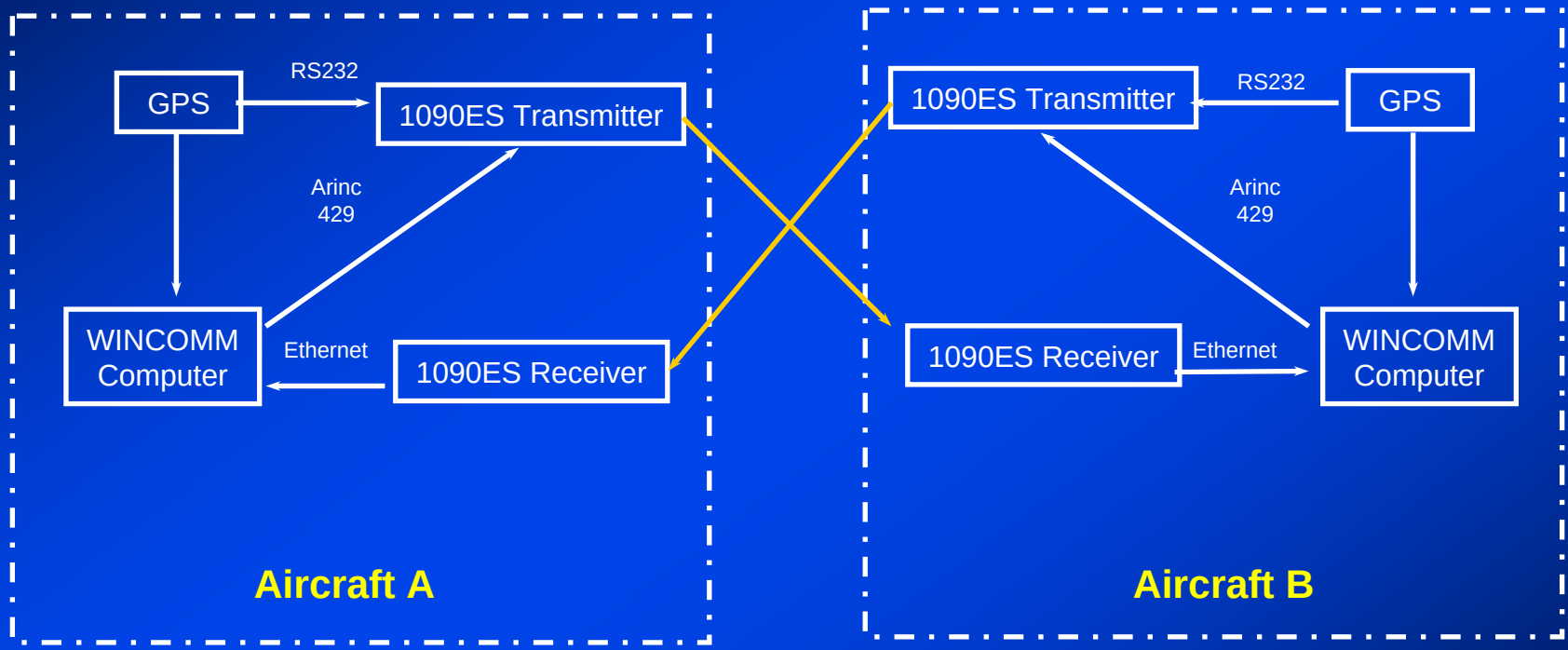
- In compliance with DO-260, with a downlink format (DF) of 17 (standard for ADS-B messages over 1090ES).

- Uses the test type code (23), and BDS codes 4 & 5 (already designated in ICAO Annex 10, Volume II, as Meteorological Hazard Report).

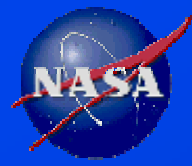
- The messages are sent as encountered turbulence exceeds one of three thresholds, but is never transmitted at a rate greater then once per 60 seconds. (For testing purposes a message is sent every 60 seconds.)

1 2 3 4 5	MSB 1 0 FORMAT TYPE CODE = 23 (TEST) 1 1 LSB 1
6 7 8	1 SUBTYPE CODE = 6 1 0
9 10 11 12 13	MSB Load-Based Parameter LSB
14 15 16 17 18 19 20	MSB Aircraft Constant LSB
21 22 23 24	Pad with Zeros

1090ES Data Flow



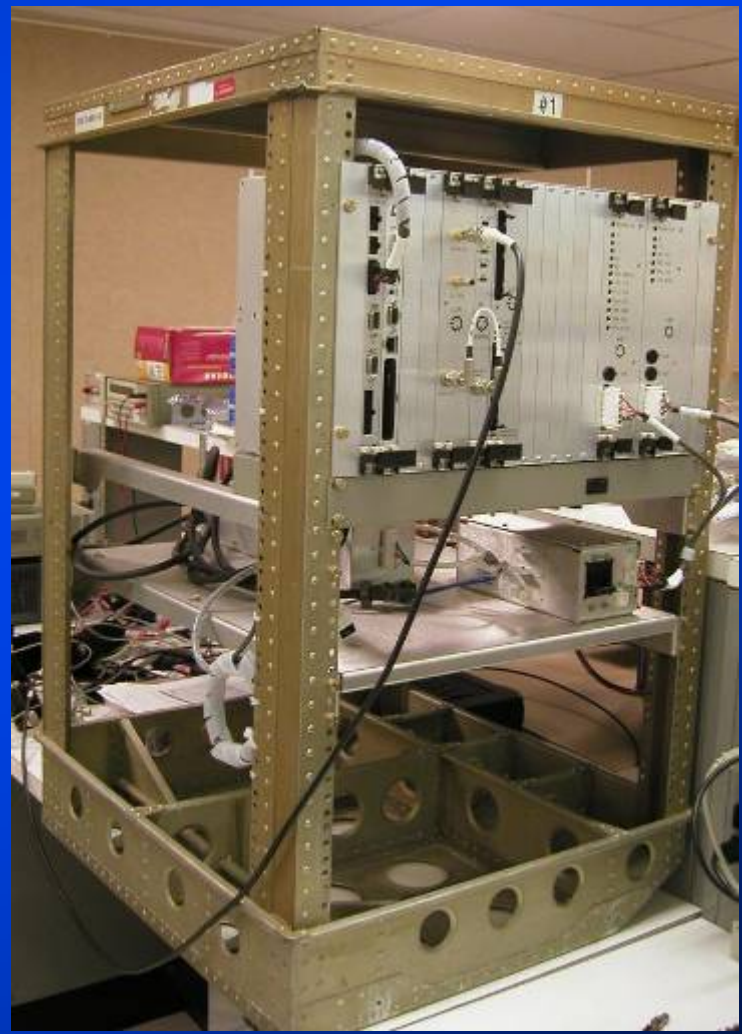
Lab Testing



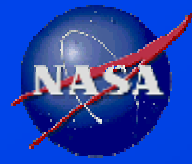
• Laboratory Testing for 1090ES was conducted at both Sensis Corp., and at NASA GRC.

• Testing utilized the Honeywell KT-73 transponder, connected to an altitude encoder test device, and to a computer via ARINC 429 for transmitting the turbulence alert messages. The Sensis 1090ES Receiver equipment was mounted in a flight rack, and cabled to the KT-73. Messages were successfully transmitted between the KT-73 and the 1090ES Remote Unit, under multiple attenuation levels.

1090ES Equipment



1090ES Flight Testing



- Flights were flown out of Cleveland, and required no deployment.

- No turbulence encounters were sought out. Turbulence alert test messages were transmitted in order to effectively utilize flight time.

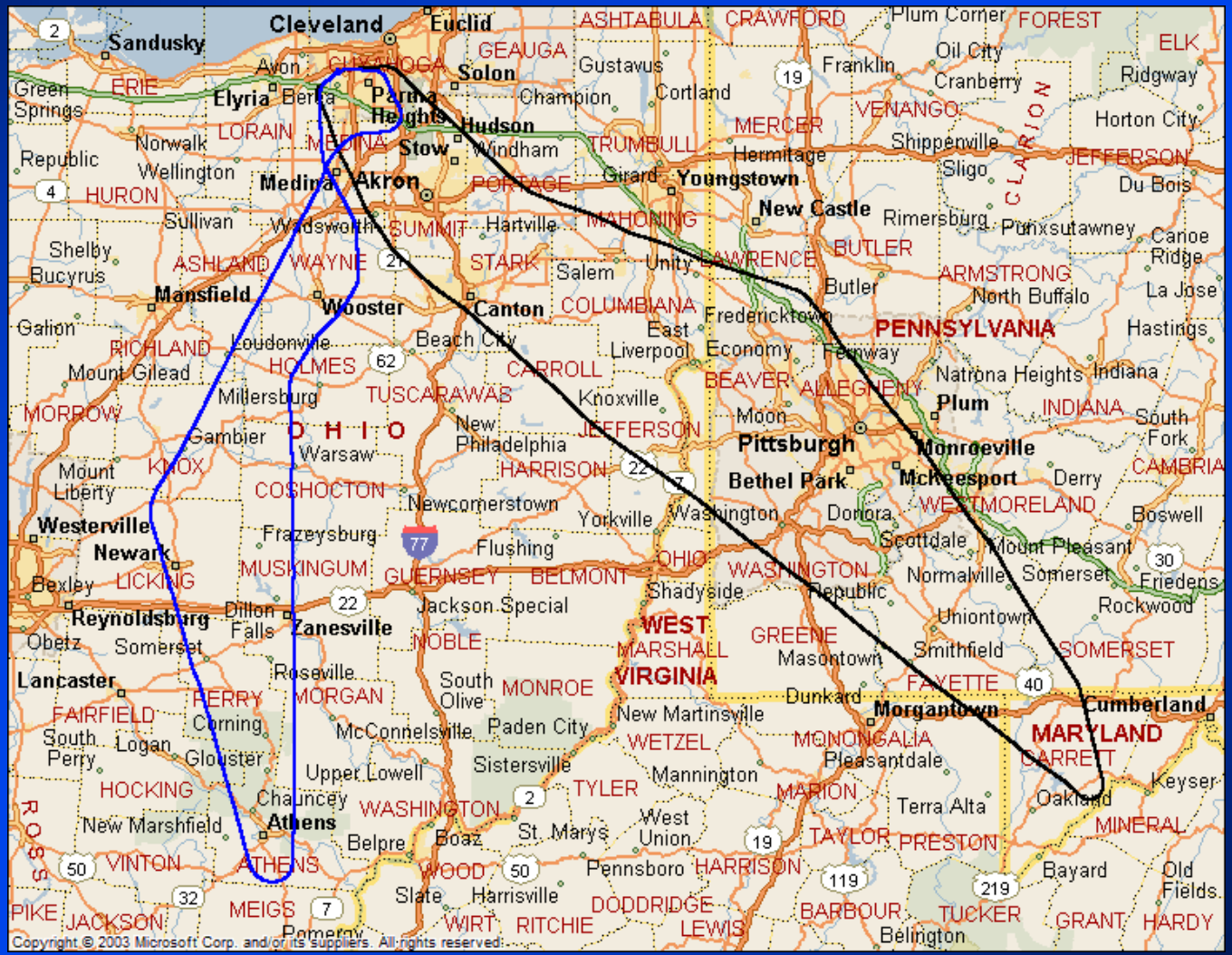
- The flights will consist of flying two aircraft at various ranges in order to perform limited testing of effective reception of turbulence alert messages.

- Data files were collected on both aircraft racks to verify transmission and reception of turbulence alert messages.

1090ES Flight #3

WINCOMM

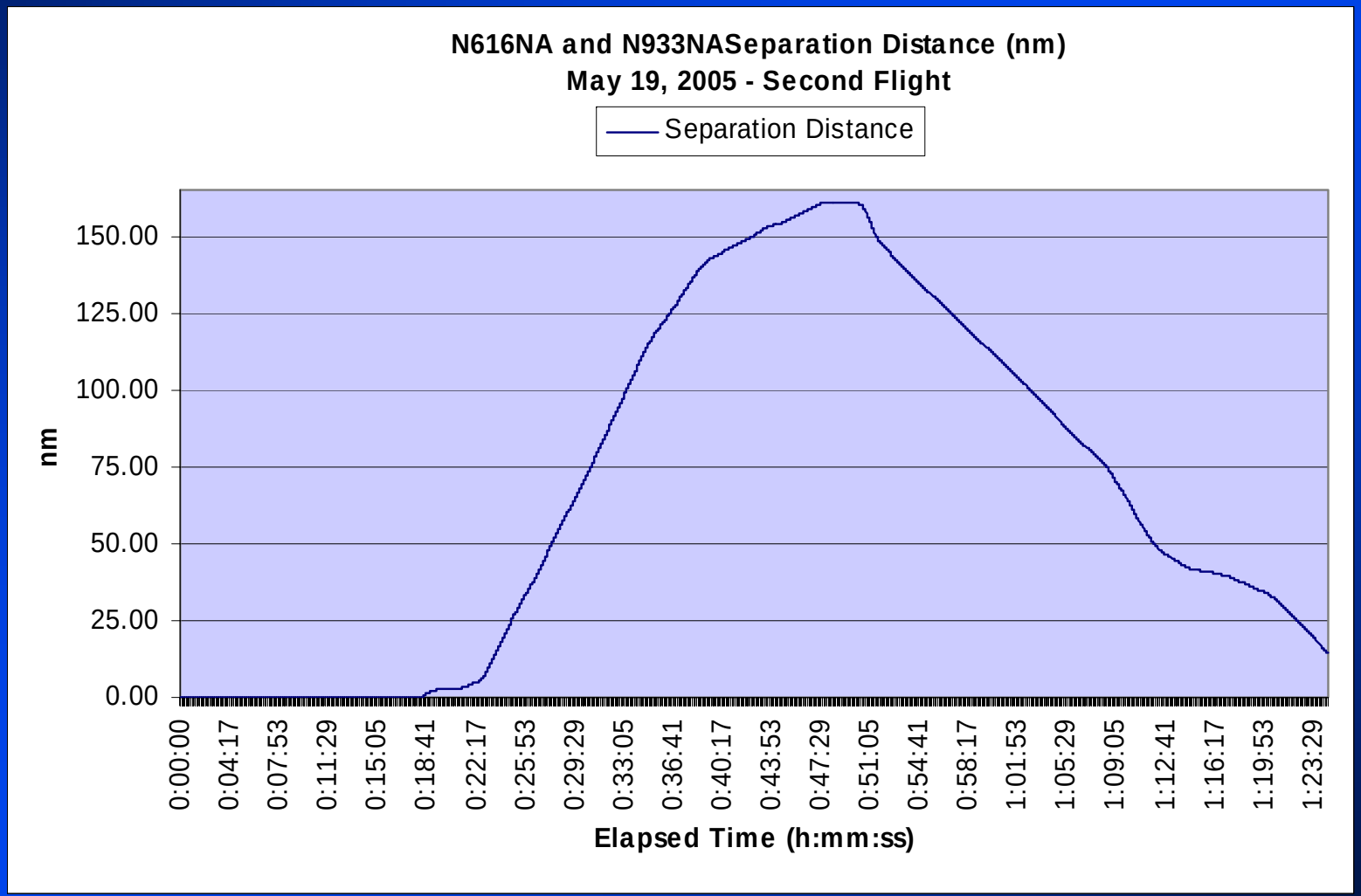
Glenn Research Center



1090ES Flight #3

WINCOMM

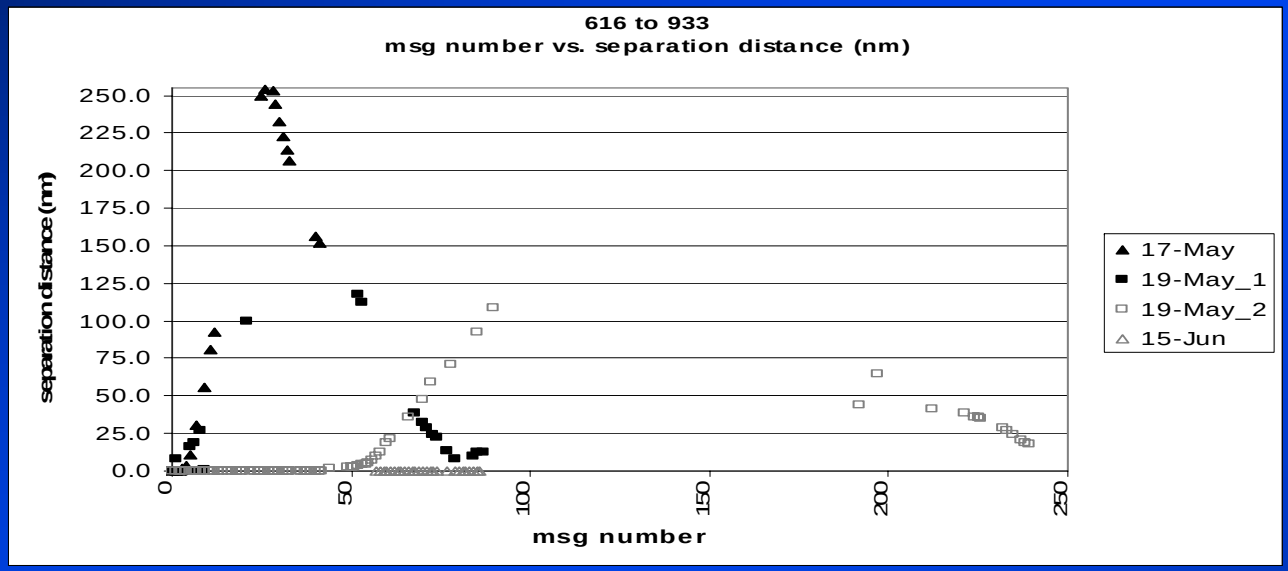
Glenn Research Center

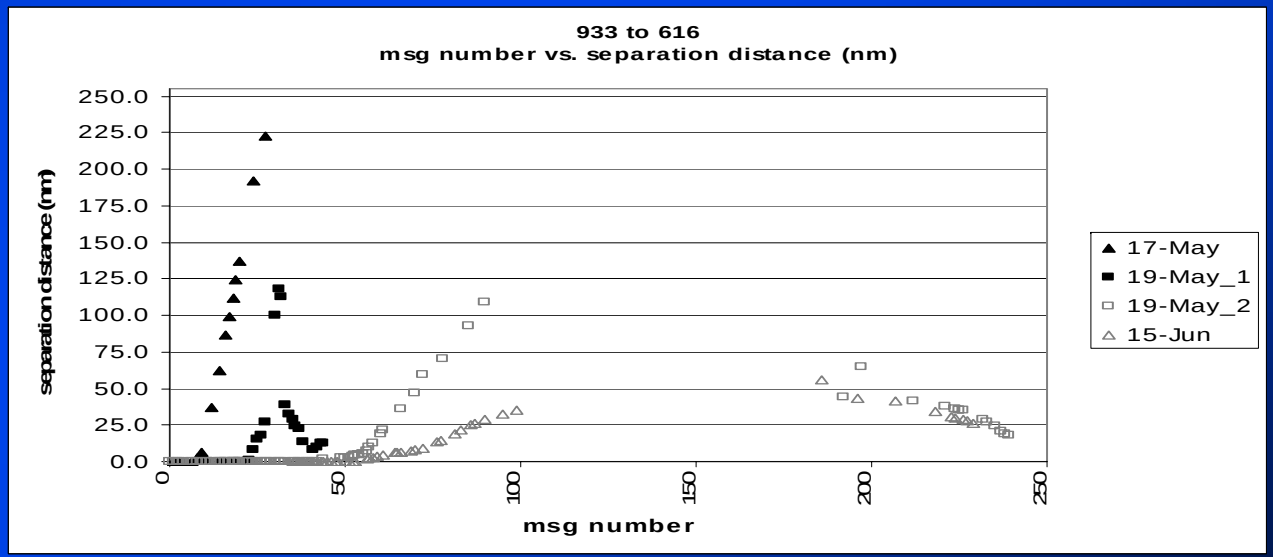


1090ES Message Reception

Message Rate	Date	Direction	Sent	Received	% Received
60sec	May 17	616 to 933	42	20	47.6%
	May 17	933 to 616	28	17	60.7%
30sec	May 19 – 1	616 to 933	98	26	26.5%
	May 19 – 1	933 to 616	130	40	30.8%
20sec	May 19 – 2	616 to 933	240	70	29.2%
	May 19 – 2	933 to 616	253	76	30.0%
	June 15	616 to 933	87	27	31.0%
	June 15	933 to 616	230	47	20.4%
	TOTAL		1108	323	29.2% (average)

1090ES Message Reception





1090ES Message Reception 3nm-100nm

Message Rate	Date	Direction	Sent	Received	% Received
60sec	May 17	616 to 933	9	6	66.7%
	May 17	933 to 616	11	5	44.5%
30sec	May 19 – 1	616 to 933	54	15	27.8%
	May 19 – 1	933 to 616	53	16	30.2%
20sec	May 19 – 2	616 to 933	98	27	27.6%
	May 19 – 2	933 to 616	105	28	26.7%
	June 15	616 to 933	0	0	0.0%
	June 15	933 to 616	171	26	15.2%
	TOTAL		501	123	24.6% (average)

1090ES Flight Team

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Objective 1&3

• Dissemination of data from own ship turbulence events to other aircraft and ground users.
• Receive and display Flight Information Service Broadcast (FIS-B) ground-air weather products.

• This objective requires at a minimum a ground-to-air broadcast link. WINCOMM's experiments will also include an air-to-ground request message, in order to facilitate the broadcast of additional value-added weather products, and a reliable air-ground turbulence alert message.

• With the additional requirements we now need a *bi-directional air-to ground datalink.*

Bi-Directional Air-Ground link

• VDL Mode 3 was the datalink chosen to meet WINCOMMs requirement of a reliable air to ground link.

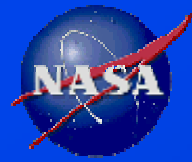
• For these tests we utilized a 2V2D configuration, with one data channel utilized for weather information communication. A voice channel was utilized during flight testing to enable air-ground coordination.

• TCP/IP was utilized over this link, as the network and transport mechanisms for data transfer. The precedence field within the IP header was mapped to VDL-3 priority levels, to give the weather messages lower priority than other traffic over the link.

VDL Mode 3 Messages

- Reliable Air-ground turbulence messages
- Reliable Air-ground message for requesting additional graphical weather products
- Broadcast Ground-Air FIS-B weather products

Air-Ground Turbulence Message

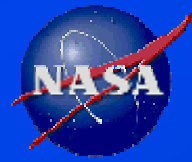


• The turbulence message will consist of the following parameters:

1. Time
2. Latitude
3. Longitude
4. Altitude
5. Aircraft Weight
6. Airspeed
7. Mach Number
8. Processed Normal Load
9. Processed Aircraft Constant

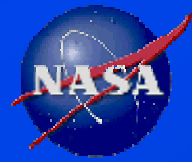
• Additional parameters are required beyond those in the turbulence alert message, to allow ground processing of the downlinked messages to be assimilated into weather prediction models and a future national turbulence weather product.

Air-Ground Request Message



- In order to allow pilots to request graphical weather products which may not be part of the standard weather product set, a request message will be transmitted to schedule the uplink of the desired product. This requested product will be transmitted as the channel is available.

Ground-Air Weather Products

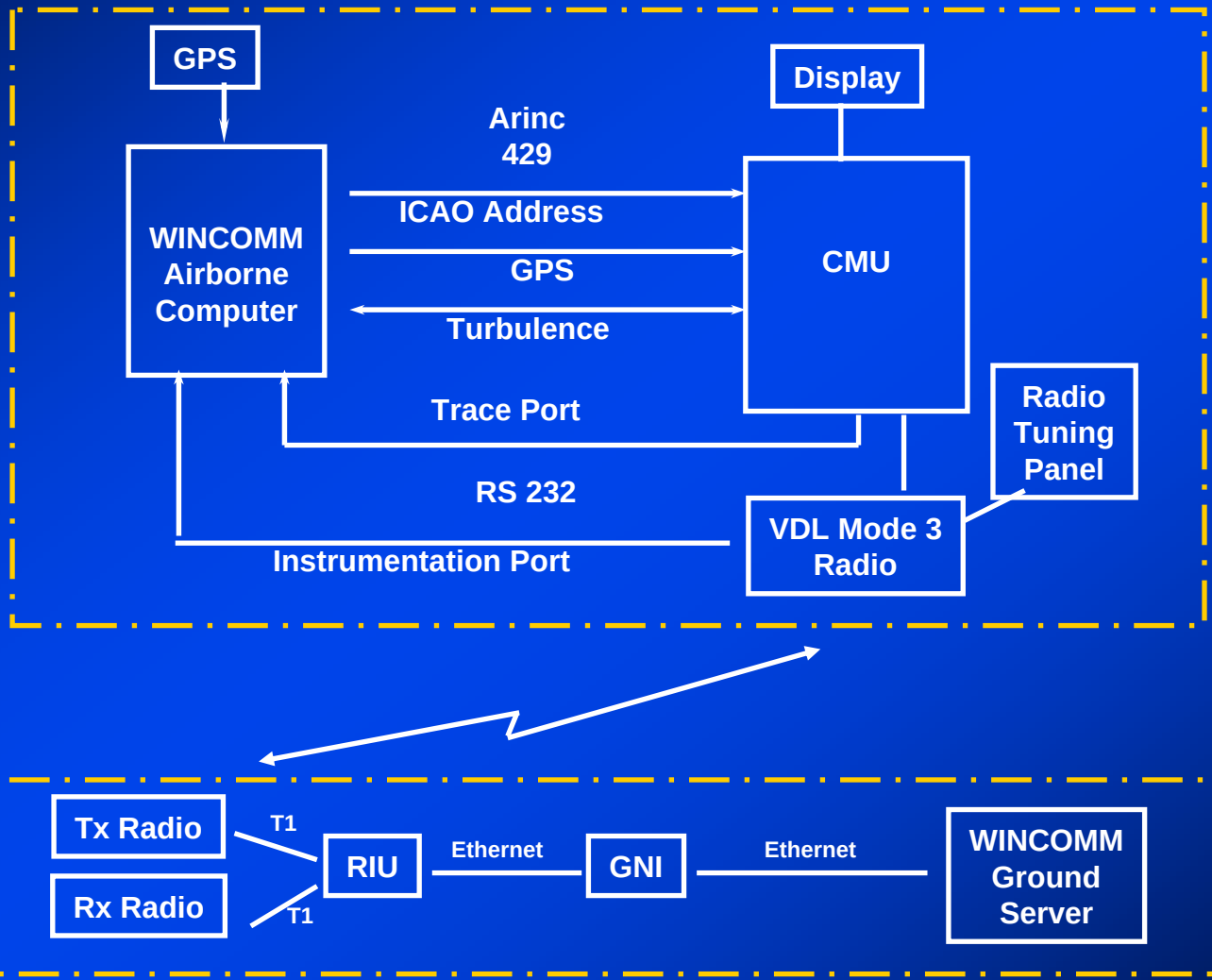


- For the purposes of the WINCOMM project, the broadcast FIS-B messages consist of the adjacent weather products. These products conform to DO-267 (FIS-B MASPS).

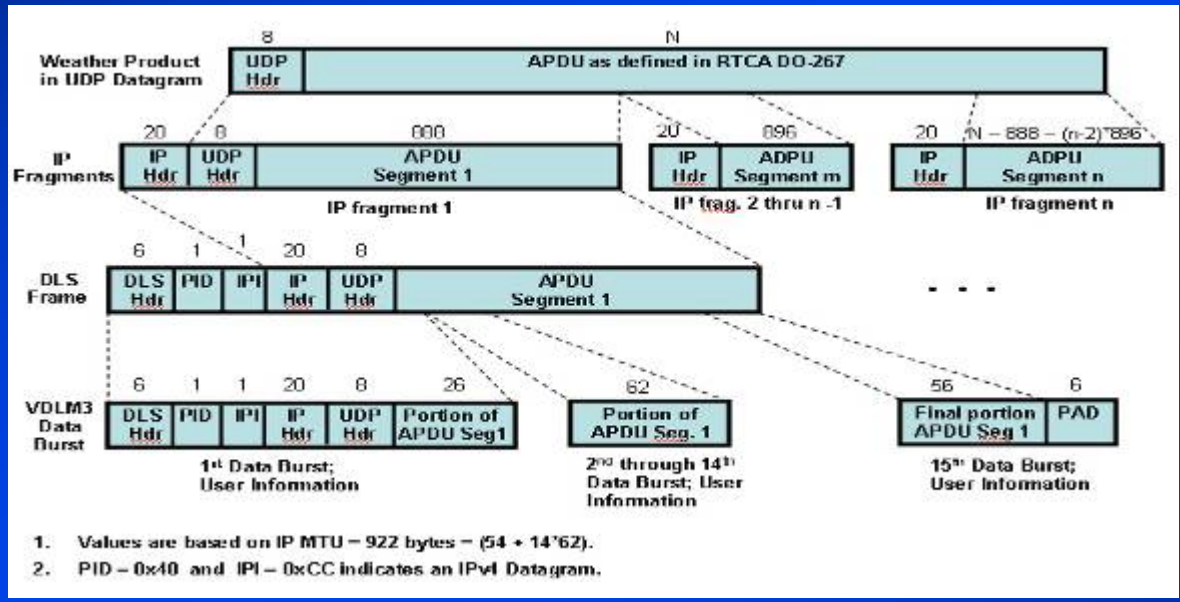
- In addition to the standard products, the pilot requested messages will be transmitted as requested and as the channel is available

Standard Products	Size (Bytes)
METARs, SPECIs	4,293
SIGMETs, Convective SIGMETs,	
AIRMETs, Severe Weather Forecast Alerts	2,544
TAFs	2,977
PIREPs	2,005
Graphical NexRad	899
Graphical Tops/Movement	1,527
Graphical Weather Depiction	2,220
Requested Products	Size (Bytes)
Graphical Winds/Temps, FL24	2,177
Graphical Winds/Temps, FL30	2,238
Graphical Winds/Temps, FL34	2,311
Graphical Turbulence, FL05	923
Graphical Turbulence, FL24	1,074
Graphical Turbulence, FL30	1,256
Graphical Turbulence, FL34	983
Graphical Icing, FL24	1,021
Graphical Icing, FL30	723
Graphical NexRad, Region: Northwest	401
Graphical NexRad, Region: Northcentral	508
Graphical NexRad, Region: Northeast	1,495
Graphical NexRad, Region: Southcentral	526
Graphical NexRad, Region: Southeast	592

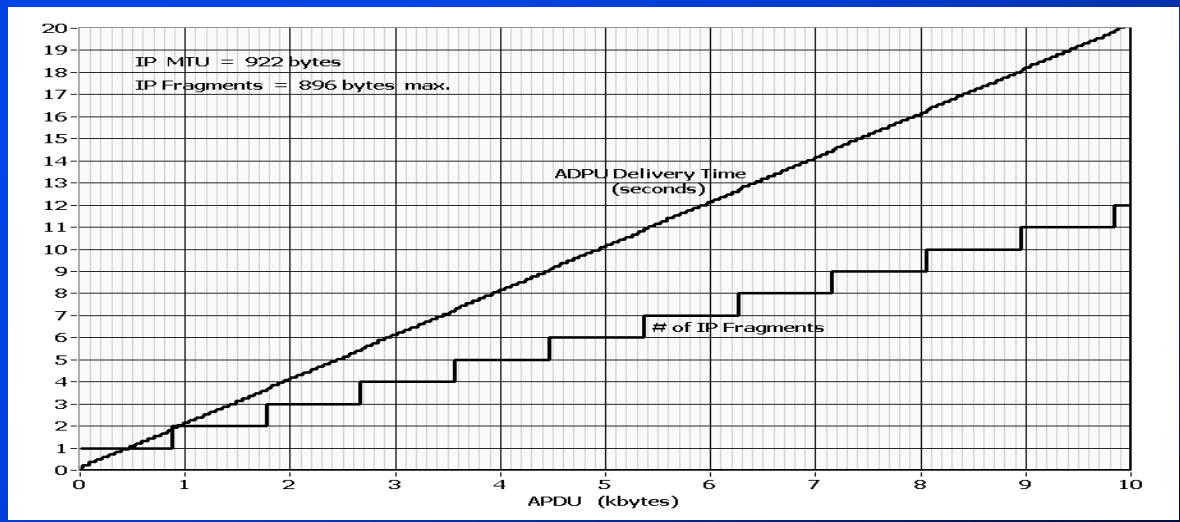
VDL Mode 3 Data Flow



VDL Mode 3

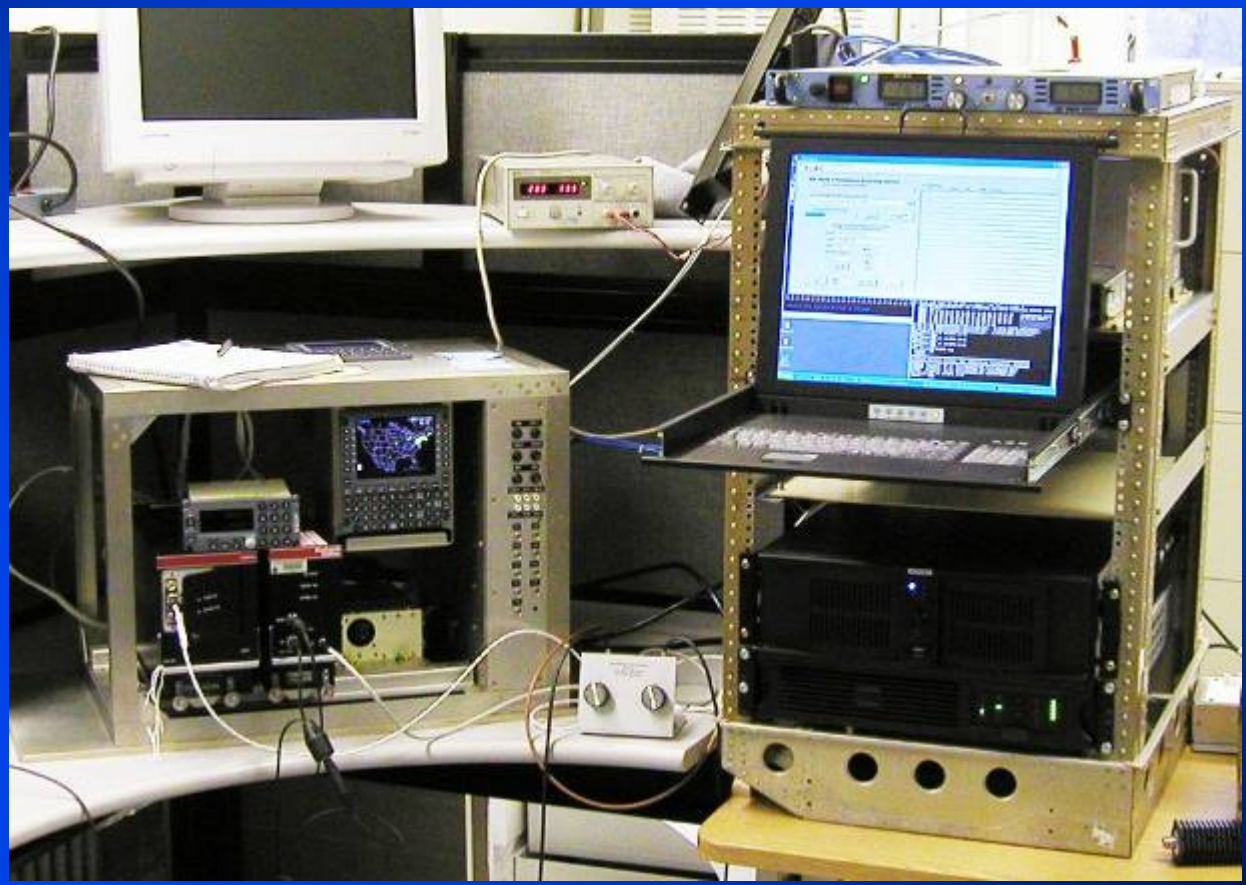


490 bytes per second (3.92 kbps)



VDL Mode 3 Lab Testing

- Lab testing was conducted at both NASA GRC and at the FAA Technical Center. These tests were conducted in both cabled and RF environments, under varying attenuation schemes.



VDL Mode 3 Ramp Testing

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VDL Mode 3 Flight Testing

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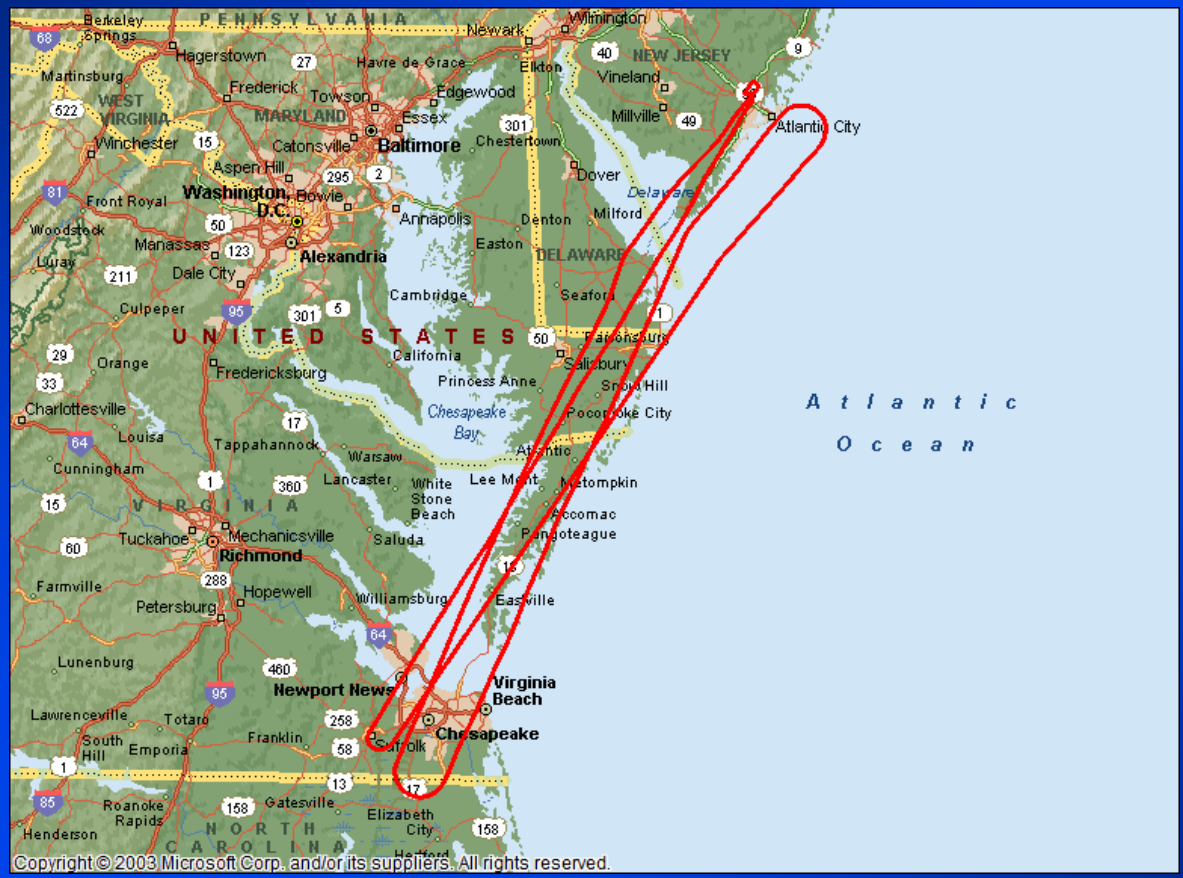
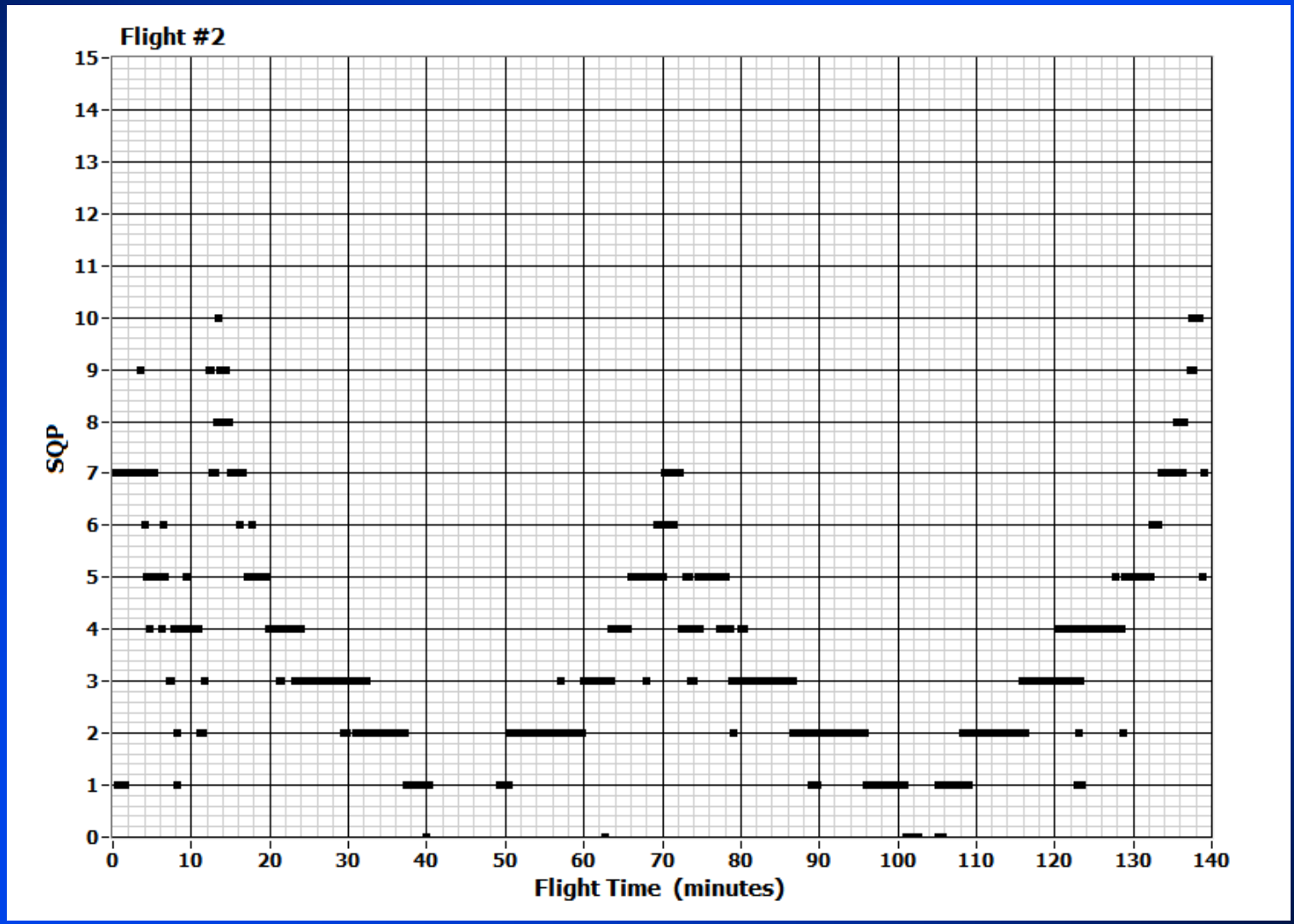
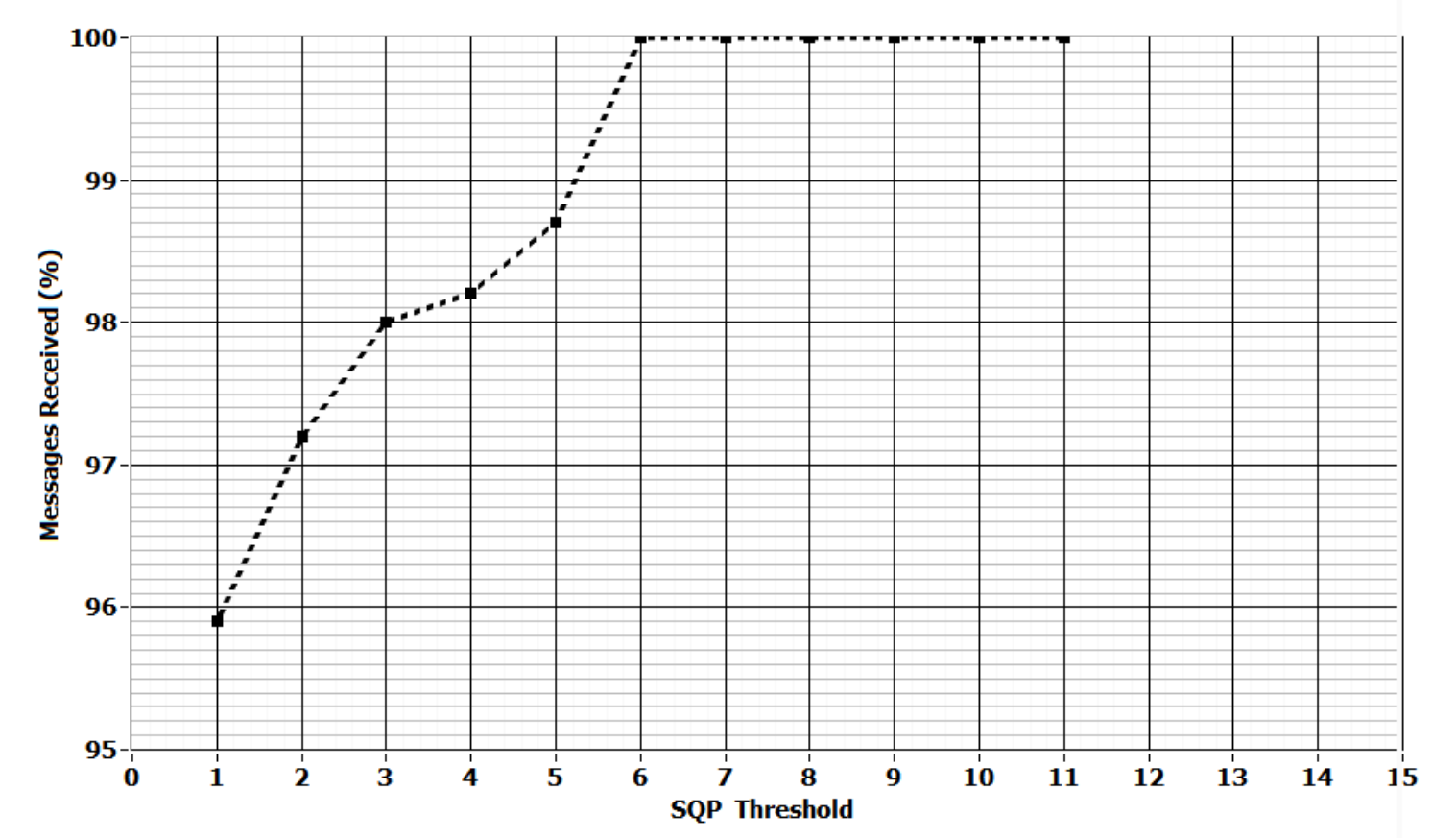


Five flights (11hrs total) were conducted between April 10-13, 2005, using the FAA Technical Center VDL-3 ground station.

Signal Quality



Standard Weather Product Reception



Standard Weather Product Reception

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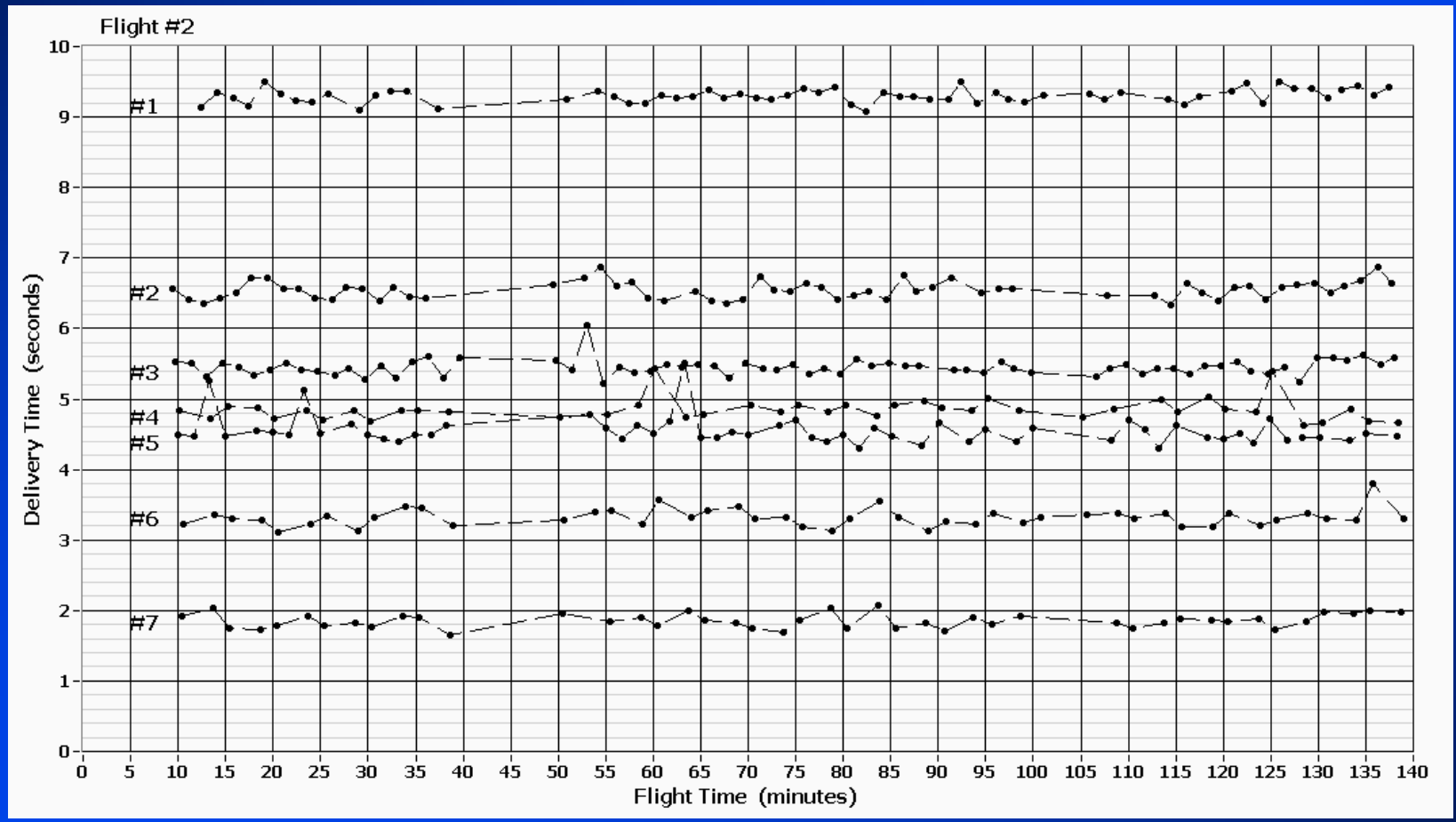
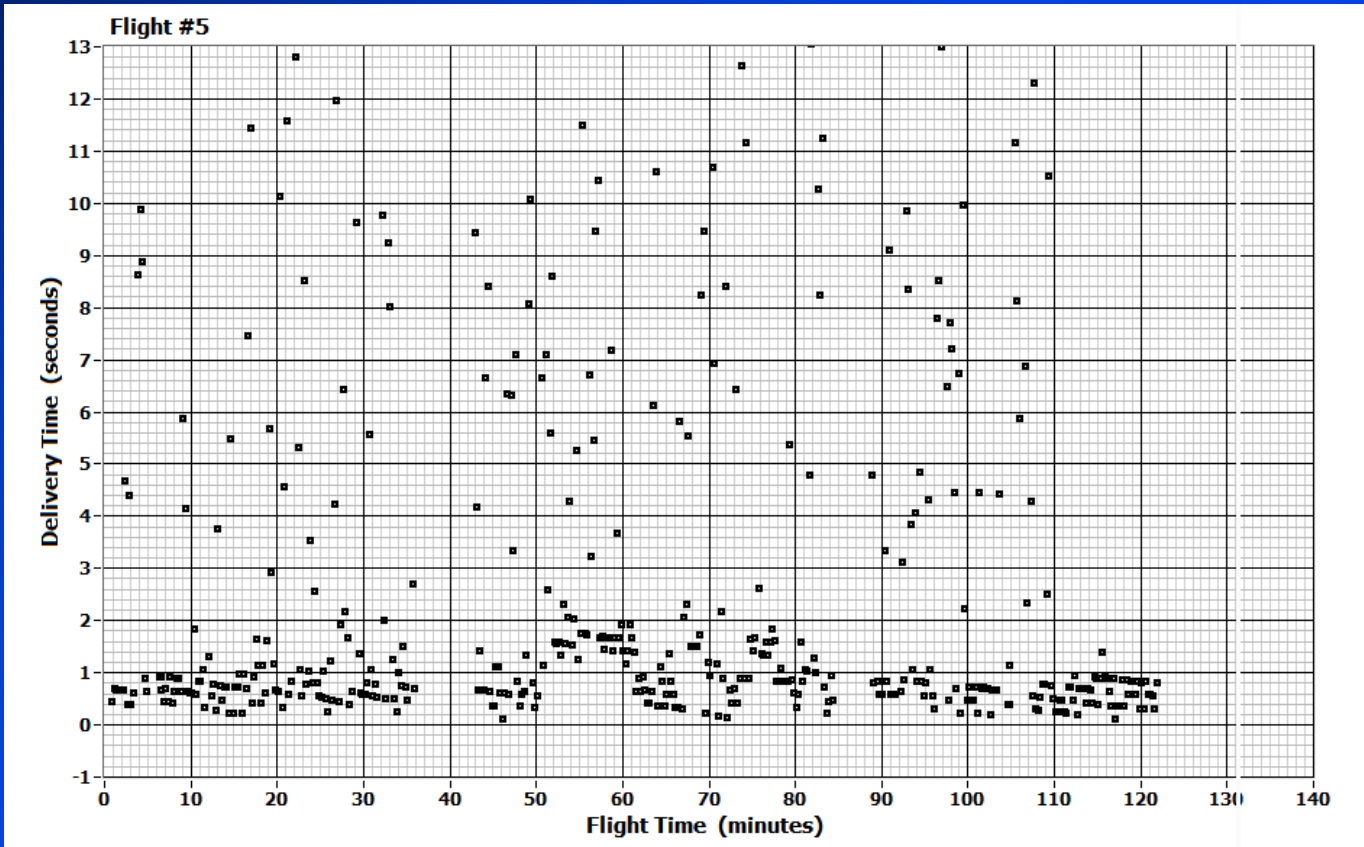


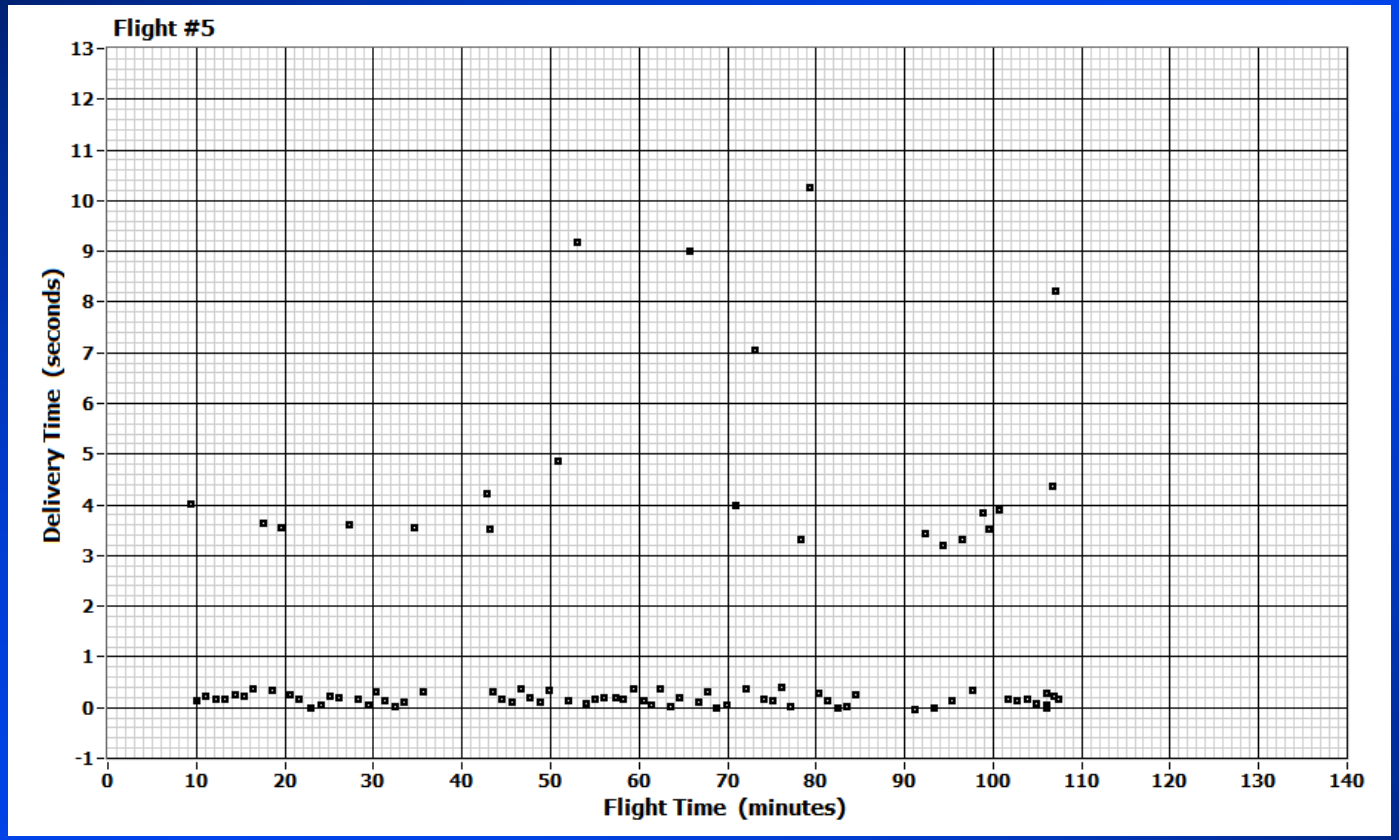
WTP	#1	#2	#3	#4	#5	#6	#7
Bytes	4,293	2,977	2,544	2,220	2,005	1,527	889
Desc.	METAR	Term. Wx	SIGMETS	Wx CONUS	PIREPS	NEXRAD	NEXRAD

Turbulence Message Reception



	Flt. #2	Flt. #3	Flt. #4	Flt. #5
TTMs Sent	136	122	217	444
TTMs Rec'd.	136	122	217	444
TTMs Lost	0	0	0	0
Retransmissions:				
at the TCP layer	5	6	20	34
at the DLS layer	55	32	49	93

Request Message Reception



	Flt. #2	Flt. #3	Flt. #4	Flt. #5
REQs Sent	16	43	43	102
REQs Rec'd.	16	43	43	102
REQs Lost	0	0	0	0
Retransmissions:				
at TCP layer	5	11	6	6
at DLS layer	4	20	8	30

Standard Weather Products

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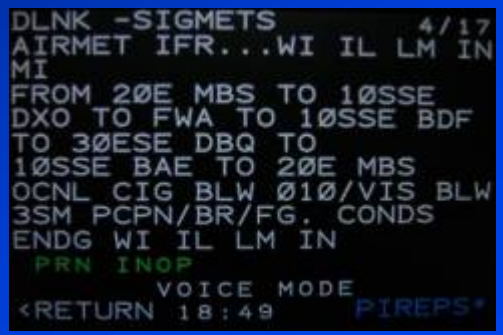
METAR, SPECI (4,293 bytes)

PIREPS (2,005 bytes)

Terminal Weather (2,977 bytes)



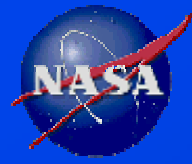
SIGMETS, AIRMETS (2,544 bytes)

NEXRAD, CONUS (889 bytes)

NEXRAD, w/tops (1,527 bytes)

Weather Depiction (2,220 bytes)

Requested Weather Products



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Winds/Temps, FL24, 00Z (2,177 bytes)

Winds/Temps, FL30, 00Z (2,238 bytes)

Winds/Temps, FL34, 00Z (2,311 bytes)

Turbulence, FL05, 00Z (923 bytes)

Turbulence, FL24, 00Z (1,074 bytes)

Turbulence, FL30, 00Z (1,256 bytes)

Turbulence, FL34, 00Z (983 bytes)

Icing, FL24, 00Z (1,021 bytes)

Icing, FL 30, 00Z (723 bytes)

Requested Weather Products

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NEXRAD, Northwest (401 bytes)

NEXRAD, Northcentral (508 bytes)

NEXRAD, Northeast (1,495 bytes)

NEXRAD, Southcentral (526 bytes)

NEXRAD, Southeast (592 bytes)

VDL-3 Team Members

WINCOMM

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VDL-3 Team Members

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Overall Architecture

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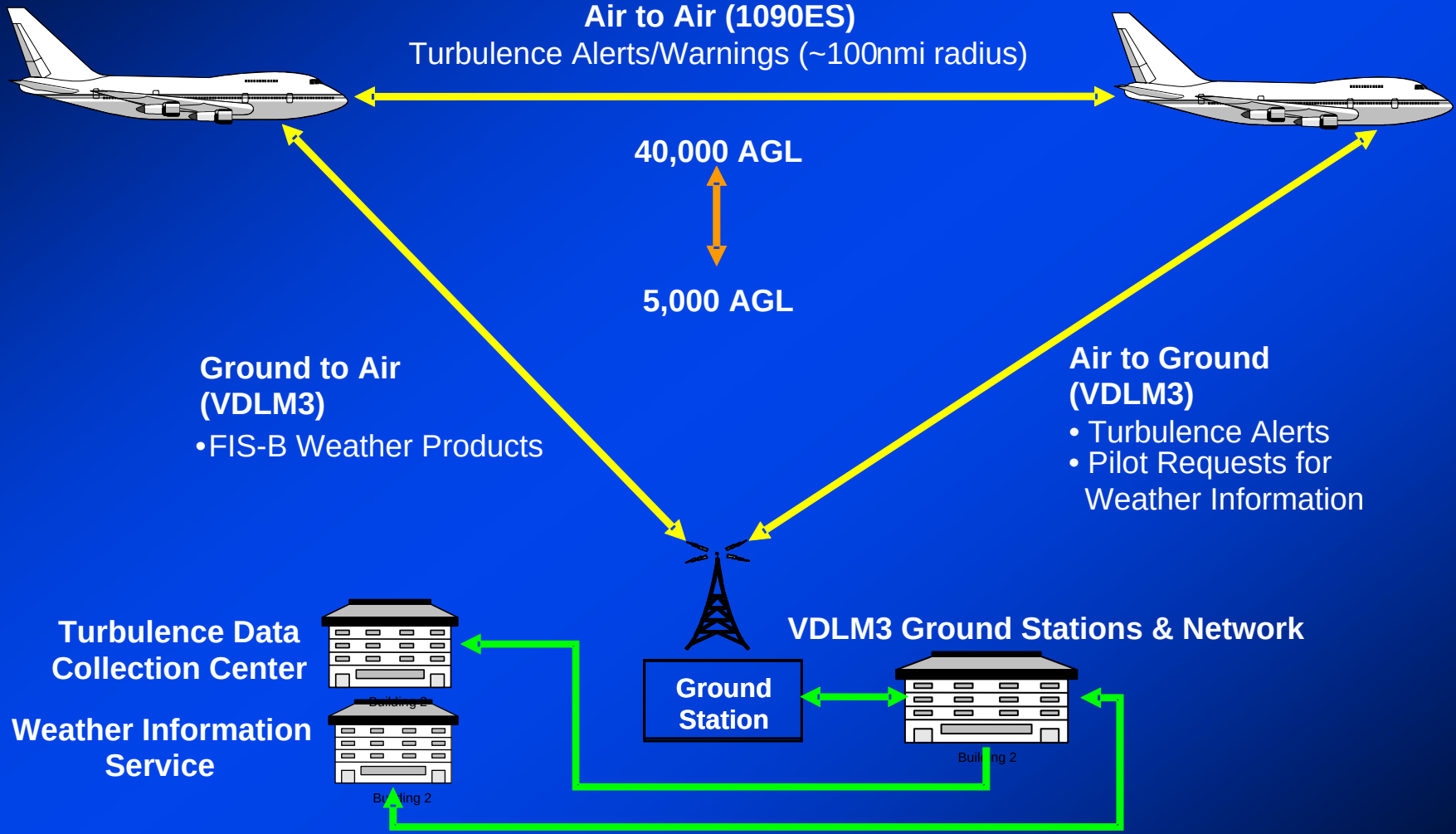

Summary

- All equipment modifications were software based in order to allow the reception and transmission of these additional messages.

- All modifications were made within the accepted standards or in a manner consistent with the standards.

- These changes were worked closely with industry partners with a path toward certification.

- 1090ES is viable datalink for transmitting turbulence alerts

- VDL-3 is viable datalink for both broadcast and 2-way weather product dissemination.


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